It's a Particle Interacting with the Associated Wave Field!

The famous double slit experiment, originally performed by Thomas Young in 1801, directs coherent light towards a screen with 2 slits. What young found was that when the slits were spaced close enough together, the light that passed through the slits interacted with each other and produced distinct bands of light and dark – which he termed interference fringes – and is typical of wave-like behavior. The wave-particle nature of light was firmly established in the early 1900s by de Broglie and Einstein, which Bohr interpreted in his complementarity principle, stating that at any given instant light, must be behaving as a wave or a particle but never both. He suggested that the observed state is likely to be determined by the equipment doing the measuring. This thinking, along with Heisenberg's uncertainty principle and Schrodinger's thought experiment, led to the current consensus of quantum theory, which states, that the very act of observing affects the observed reality.

In quantum mechanics each particle is represented by a "probability wave" i.e. a weighted distribution of probable possibilities. The Copenhagen interpretation explains this as all particles being in all possible states – a superposition of states – until the moment of observation (measurement) when the wave function is said to collapse into a definite state. How this particle solidifies into the 'observed' state is a question yet to be answered.

It is important to remember that this idea of probability lies in the mathematics. The fact that the standard equations describing quantum mechanics are defined in terms of probability waves does not imply that nature is inherently probabilistic. Instead it is our inability to ascertain what nature is doing, which results in a probabilistic solution.

For example, based on what we know in 'this' moment we can infer an attribute or measurement of a system, where how much we know about the system effects the degree of accuracy of our inference. So for a simple system we may be able to predict an exact value – which agrees exactly with the measurement. The more complicated the system, the more broad the prediction i.e. we cannot predict an exact value only a range of values – a probability.

The double slit experiment has since been repeated many times, where beams of electrons are propelled one by one towards a screen with 2 slits. As expected the interference pattern emerges on the screen, implying that the electrons went through both slits simultaneously – thus acting as a wave. However, when a 'which path' (WP) detector is placed in front of one of the slits, as demonstrated by **Buks et al. (1997)**, the wave like nature disappears implying the quantum weirdness of the Copenhagen interpretation – that the act of observing affects the observed reality.

However, this idea of superposition of states in the quantum world does not seem to relate to the workings of our everyday world. For example, if there is a classroom full of girls. The door is shut and we have no information about the girls except that they are aged 15-16. If you want to determine the height of Sheila, unless you go into the classroom and measure her (or have access to her private records), then the only way to determine her height is – probability! You can therefore determine her height as a probability wave with the possibilities weighted according to a Gaussian distribution (Bell curve). This does not mean that she existed in all possible heights and only took the exact form when we opened the door and measured her.

So why should the quantum world be any different?

A more intuitive and classical approach to understanding Young's double slit experiment was first explained by de Broglie, who in 1927, suggests that the electron just passes through one slit but is influenced by a pilot wave. The pilot wave thus goes through each slit creating an interference pattern, where the particle is drawn to where the waves have constructive interference and not destructive interference. The electron is therefore only found to be located within the constructive interference – which in the equations of Quantum Mechanics is represented in the form of a 'likely' probability wave. Pilot wave theory thus makes all the predictions of the Copenhagen interpretation but without any of the quantum weirdness.

In contrast to the Copenhagen interpretation, de Broglie's pilot wave-theory suggests that particles have a definite trajectory but that we are unable to deduce its exact path. This introduces hidden variables to the wave equation which, according to John Von Neumann, was found to be impossible. His claims were subsequently falsified by John Stewart Bell and in 1952 Bohm re-established pilot-wave theory which became known as de Broglie-Bohm theory or Bohmian mechanics.

Recent experiments by **Couder et al. (2005)** show the fascinating effects of pilot-waves as well as the quantum features that emerge. In their experiment they showed that not only does an oil drop bounce indefinitely on the surface of a vibrating fluid bath **(Walker, 1978)** but that by vibrating the fluid bath, which in this case was silicon, at a specific frequency the oil droplet is induced to bounce along the surface of liquid, creating ripples. What is happening is that as the amplitude of the vibration is increased, the drop achieves resonance with its Faraday wave field and is propelled along the bath surface. When the oil droplet, or "walker", interacts with these ripples the particle-wave interaction guides the oil droplet – thus a pilot wave is formed.

The results of this experiment agree with de Broglie's predictions and provide an alternative explanation for quantum weirdness:

Double Slit Experiment

- The droplet passes through one slit or the other, while the pilot wave passes through both creating an interference pattern, showing the effects of wave-particle duality.
- The pilot wave always guides the droplet to locations of constructive interference, just as predicted by the equations of quantum mechanics, which allows us to accurately predict its probability wave.
- Any disturbance to the pilot wave destroys the interference pattern, just as the presence of a WP detector induces dephasing – such that no interference pattern is observed when the trajectory of the particle is ascertained.

Quantum Tunneling

- **Eddi et al. (2009)** investigates the motion of the "walker" when it collides with barriers of various thicknesses and finds that it undergoes a form of tunneling, where the crossing probability decreases exponentially with increasing barrier width
- The frequency of the vibrating fluid is depth dependent, such that an imposed acceleration may form a walker in the deep end but not in the shallow end. This depth dependence is relied upon in the experiments and thus creates a barrier between the shallow end and the deep end, where if a walker from the deep end reaches the border of the shallow region it is reflected away. This repulsion comes from the interaction of the droplet with the waves reflected by the boundary. When it comes close to the boundary an exponentially damped wave is observed over it.
- The probability of escaping the barrier decreases with increasing velocity and decreasing barrier thickness. The non-local interaction with the reflected waves leads to diverging trajectories. When the trajectories become disordered the collisions with the walls show a larger variety of angles, where those with near normal incidence can lead to an escape. The partial transmission of its waves through thin barriers results in a probabilistic crossing of the whole structure!
- So basically the associated wave of the walker is transmitted through thin barriers, which can result in the walker also being transmitted with the wave, depending on the trajectory as mentioned above. The wave that is transmitted is of a much lower amplitude, reduced exponentially as predicted by quantum theory.

Spontaneous Creation and Subsequent Annihilation

- Subsurface bubbles form on the silicon bath which when in contact with the droplet/particle they annihilate. This effect is reminiscent of the mutual destruction of matter and anti-matter particles.

Occupation of Discrete Energy Levels

- When confined to a circular cavity – known as corrals – the "walker" explores the cavity propelled by its guidance wave winding a chaotic path of variable velocities. Every bounce of the droplet leaves an imprint or "path memory" in the form of ripples, which then interacts with and influences the droplets future path within the cavity. Eventually a pattern of concentric rings emerges. This pattern corresponds to the Faraday wave mode of the cavity and is the same as the probability distribution predicted by quantum mechanics.
- If a magnet is placed in the centre of the cavity, the bouncing droplet is observed to occupy a discrete set of orbits around the magnet, each with a characteristic energy level and angular momentum. This is much like an electron occupying discrete energy levels around a nucleus, and is considered a defining feature of quantum mechanics.

If these effects are observed in the dynamics of a fluid bath and a droplet made from that silicon bath, then it is not unreasonable to assume that the same would be true for the vacuum and a particle made of that vacuum.

In any case, these findings are truly significant, however, in terms of quantum mechanics accepting such a change of perspective we may be waiting a long time. For some, at least we have another more intuitive and obvious understanding of the experimental result at the quantum level.

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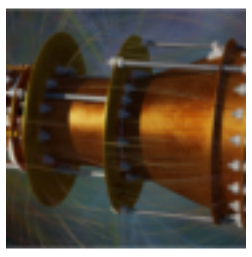

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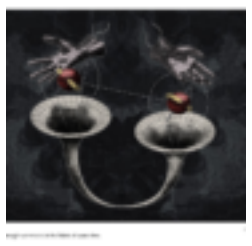

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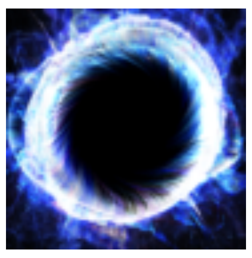

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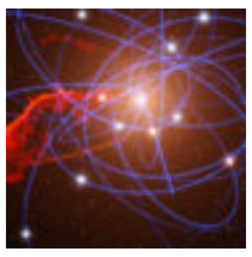

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